ACCP Updates in Therapeutics®
2015: Critical Care Pharmacy
Preparatory Review Course

Acute Cardiac Care

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Learning Objectives

1. Manage cardiac arrest from the initiation of basic life support to the use of post–cardiac arrest care.
2. List the indications and contraindications for medication administration during cardiac arrest.
3. Recognize the utility of therapeutic hypothermia and the patient groups to whom it should be applied.
4. State the common complications of therapeutic hypothermia and explain how to ameliorate them.
5. Define the different presentations of hypertensive crisis.
6. Outline the therapeutic goals and clinical indications for the medications used in hypertensive emergency.

Abbreviations in This Chapter

ACLS	Advanced cardiac life support
AED	Automated external defibrillator
BLS	Basic life support
CPR	Cardiopulmonary resuscitation
ED	Emergency department
ICP	Intracranial pressure
ICU	Intensive care unit
MAP	Mean arterial pressure
MICU	Medical intensive care unit
PEA	Pulseless electrical activity
ROSC	Return of spontaneous circulation
SCA	Sudden cardiac arrest
VF	Ventricular fibrillation
VT	Ventricular tachycardia

Self-Assessment Questions

Answers and explanations to these questions may be found at the end of this chapter.

Questions 1–5 pertain to the following case.

T.B. is a 72-year-old man with a history of atrial fibrillation, coronary artery disease after drug-eluting stent placement in 2009, heart failure with reduced ejection fraction (although his most recent ejection fraction was 45% on echocardiogram in 2013), and gastroesophogeal reflux disease. T.B. is sent to the catheterization laboratory for suspected acute myocardial infarction. Laboratory values for T.B. are as follows: international normalized ratio (INR) 1, platelet count 200,000/mm^3, hemoglobin 12 g/dL, serum creatinine (SCr) 1.7 mg/dL (baseline 1.5 mg/dL), white blood cell count (WBC) 17 x 10^3 cells/mm^3, and aspartate aminotransferase (AST) 100 IU/L. He is admitted to the coronary care unit for observation after catheterization when he suddenly loses consciousness and becomes pulseless. The coronary care unit team of which you are part is called to the bedside. Of note, T.B. has peripheral intravenous access and was on room air by nasal cannula before this event.

1. Which is most accurate regarding the appropriate first steps in T.B.'s resuscitation?
   A. T.B. needs to be emergently intubated first because this is likely a hypoxic pulmonary arrest.
   B. T.B. should first have a central line placed because he will need vasopressors, and they are preferred to be administered centrally.
   C. T.B. should have pads placed when starting cardiopulmonary resuscitation (CPR), beginning with chest compressions.
   D. T.B. should have pads placed when CPR is initated, beginning with 2 breaths by bag-mask ventilator first.

2. The monitor reveals that T.B. is in ventricular fibrillation (VF). Which is the most appropriate management of T.B.'s VF arrest?
   A. T.B. should receive a shock as soon as possible with your biphasic defibrillator (manufacturer recommendation 200 J).
   B. T.B. should receive intravenous amiodarone at a dose of 300 mg x 1 as soon as possible.
   C. T.B. should receive intravenous atropine at a dose of 0.4 mg x 1 as soon as possible.
   D. T.B. should receive emergent pacing for his VF arrest because it is superior to other interventions.

3. T.B.'s rhythm changes from VF to pulseless electrical activity (PEA) on the monitor. Which is the most appropriate management of T.B.'s PEA arrest?
   A. T.B. should receive a shock as soon as possible with your biphasic defibrillator (manufacturer recommendation 200 J)
   B. T.B. should receive high-quality chest compressions and consideration of the treatable causes of cardiac arrest.

C. T.B. should receive intravenous lidocaine 1 mg/kg x 1, followed by 0.5 mg/kg every 5 minutes until a maximum total dose of 3 mg/kg because this is of substantial benefit in PEA arrest.
D. T.B. should receive intravenous atropine 0.4 mg x 1 as soon as possible because this is of substantial benefit in PEA arrest.

4. T.B. has return of spontaneous circulation (ROSC) after 15 minutes of total resuscitation. Your team is deciding whether targeted temperature management (therapeutic hypothermia) would be appropriate for T.B. Which is most accurate regarding targeted temperature management for T.B.?
   A. T.B. should not be considered for targeted temperature management because he had a VF arrest first, and most data come from PEA arrest.
   B. T.B. should not be considered for targeted temperature management because he has transaminitis, which is a contraindication for therapeutic hypothermia.
   C. T.B. should be considered for targeted temperateure management, but his renal function should be vigilantly monitored because of his baseline SCr and the worsening of glomerular filtration that occurs during cooling with therapeutic hypothermia.
   D. T.B. should be considered for targeted temperature management, but empiric thrombolysis should be initiated concurrently because hypothermia places patients at a significant risk of clotting.

5. Your team wants further information about the literature regarding therapeutic hypothermia. Which is the most appropriate information regarding the data to support therapeutic hypothermia?
   A. Therapeutic hypothermia improves survival in VF cardiac arrests and therefore should be reserved for these patients.
   B. Therapeutic hypothermia is the only intervention shown to improve neurologic outcomes and therefore has been applied to most cardiac arrests, independent of cause.
   C. Therapeutic hypothermia is superior when targeting a core temperature of 36°C compared with 33°C in recent studies.
   D. Therapeutic hypothermia has been most studied in patients with asystole; therefore, some institutions do not apply the results to patients with other presenting rhythms (ventricular tachycardia [VT], VF, and PEA).

Questions 6–8 pertain to the following case.

J.H. is a 48-year-old woman with no known medical history who presents to the emergency department (ED) for acute onset of shortness of breath, side pain, and some blurry vision. She denies any illicit drug use or cigarette use, but she confirms social alcohol intake (about 3 drinks per week). Urine toxicology is negative. Initial vital signs are as follows: blood pressure (BP) 202/140 mm Hg, heart rate (HR) 88 beats/minute, respiratory rate (RR) 22 breaths/minute, and pain 4/10 (chest and side pain). Initial laboratory values are as follows: SCr 0.8 mg/dL, AST 60 U/L, ALT 45 U/L, lipase 20 U/L, total bilirubin (Tbil) 1 mg/dL, direct bilirubin (Dbil) 0.4 mg/dL, WBC 6 x 10^3 cells/mm^3, hemoglobin 11 mg/dL, troponin T less than 0.01 ng/mL, and D-dimer less than 0.5 mcg/mL. Chest radiography shows moderate bilateral pleural effusions and no focal consolidations. Chest computed tomography (CT) is negative for pulmonary embolism. Of note, J.H. is taking no prescription or over-the-counter medications.

6. Which is most accurate regarding the classification of J.H.'s BP?
   A. J.H. is having a hypertensive urgency because she has no signs of target organ damage with severe acute BP elevations.
   B. J.H. is having a hypertensive urgency because she has signs of target organ damage with severe acute BP elevations.
   C. J.H. is having a hypertensive emergency because she has no signs of target organ damage with severe acute BP elevations.
   D. J.H. is having a hypertensive emergency because she has signs of target organ damage with severe acute BP elevations.

7. Which is most appropriate regarding the management of J.H.'s BP?

   A. J.H. should be initiated on phentolamine 1 mg intravenously every 30 minutes as needed because she has a unique indication for phentolamine.
   B. J.H. should be initiated on metoprolol 25 mg orally every 12 hours because rapid BP reduction is not indicated.
   C. J.H. should be initiated on nitroprusside 0.25 mcg/kg/minute by continuous intravenous infusion because it can be used safely in the first 24 hours.
   D. J.H. should be initiated on enalaprilat 10 mg intravenously every 6 hours because it can be used safely in the first 24 hours.

8. Which is the most appropriate goal for J.H.'s BP reduction?

   A. Goal mean arterial pressure (MAP) reduction of 25% over the first 60 minutes.
   B. Goal MAP reduction of 50% over the first 60 minutes.
   C. Goal MAP reduction of 25% over the first 24 hours.
   D. Goal MAP reduction of 50% over the first 24 hours.

I. ADVANCED CARDIAC LIFE SUPPORT

A. Background
1. Foundation of advanced cardiac life support (ACLS) is effective and timely basic life support (BLS).
2. Sudden cardiac arrest (SCA) continues to be a leading cause of death in many parts of world.
3. SCA can vary in etiology (noncardiac vs. cardiac), circumstances (unwitnessed vs. witnessed), and setting (in vs. out of hospital).
4. Because of heterogeneity, action links that are denoted the "Chain of Survival" were developed for guidance and include (Circulation 2010;121:948-54; Circulation 2010;122:S685-705):
    a. Immediate recognition of SCA and activation of the emergency response system
    b. Early CPR that emphasizes chest compressions
    c. Rapid defibrillation, if indicated
    d. Effective ACLS
        i. Airway management and ventilation support
        ii. Treatment of bradyarrhythmias and tachyarrhythmias
        iii. Integrated post–cardiac arrest care
5. When following the Chain of Survival effectively, can affect survival (e.g., with out-of-hospital, witnessed VF arrest survival rates that can approach 50%) (Circulation 2006;114:2760-5)
6. Because BLS and ACLS are often experienced as a team approach in the hospital setting, it is imperative to be familiar with all aspects of BLS and ACLS in order to fulfill any role during the arrest situation.

B. BLS – Chain of Survival
1. Immediate recognition of SCA and activation of emergency response system:
    a. Unresponsive patient or witnessed sudden collapse with absent or gasping abnormal breathing (Circulation 2010;122:S68-705; Acad Emerg Med 2007;14:877-83)
        i. Ensure that scene is safe.
        ii. Check for response by tapping on shoulder and shouting at victim; simultaneously check for normal breathing.
        iii. Activate emergency response system (e.g., facility emergency response team), and follow instructions from trained dispatchers/responders (Ann Emerg Med 1993;22:354-65).
2. Begin CPR. Follow the sequence of C-A-B (compressions-airway-breathing).
    a. Chest compressions an essential component of CPR
        i. Often not provided by laypeople until professional emergency responders arrive (Circ Cardiovasc Qual Outcomes 2010;3:63-81)
        ii. Both an increase in intrathoracic pressure and a direct compression of the heart lead to perfusion and oxygen delivery to the brain and myocardium.
        iii. All patients with SCA should receive chest compressions (Acta Anaesthesiol Scand 2008;52:914-9).
        iv. Place patient on a hard surface, use backboard (unless it will cause interruptions in chest compressions, delay in initiation of CPR, or dislodgment of lines/tubing), and/or deflate air-filled mattresses (J Intensive Care Med 2009;24:195-9; Acta Anaestheiol Scand 2007;51:747-50; Resuscitation 2004;61:55-61).
        v. Compress at a rate of at least 100 compressions/minute at a depth of at least 2 inches, and allow chest recoil after each compression to avoid decreases in coronary perfusion, cardiac index, myocardial blood flow, and cerebral perfusion (Crit Care Med 2010;38:1141-6; Resuscitation 2006;71:137-45; Resuscitation 2006;71:341-51; Resuscitation 2005;64:363-72).
        vi. Actual number of chest compressions given per minute is a function of the compression rate and proportion of time without interruption. Goal is to minimize interruptions to chest compressions.

(a) Increasing the number of compressions given per minute can affect survival from cardiac arrest (JAMA 2008;299:1158-64) and is a determinant of ROSC and neurologically intact survival (Circulation 2009;120:1241-7; Circulation 2005;111:428-34).
(b) Rescuer fatigue is common and may lead to inadequate compression quality (Resuscitation 2009;80:918-4). Recommended to change compressors every 2 minutes (or after five cycles of compressions at a rate of 30:2 compressions/ventilation) with no more than 5 seconds between changes (Resuscitation 2009;80:1015-8).
(c) Providers have difficulty and take too long to check for a pulse (Resuscitation 2000;44:195-201). Pulse checks (including initial) should last no more than 10 seconds.
(d) Compression-first (or "compression only") CPR decreases time until first compression (Resuscitation 2004;62:283-9) and may increase layperson participation but needs to be validated to replace traditional compression-ventilation CPR

Patient Case

1. A.C., a 50-year-old man with a history of gastroesophageal reflux disorder and chronic obstructive lung disease, was admitted for shortness of breath, palpitations, and presumed exacerbation of his lung disease. On hospital admission day 4, A.C. has witnessed cardiac arrest on the medicine unit. The emergency response team of which you are part is called, and when you arrive, the bedside nurse has already begun chest compressions. Which insight would be best shared regarding chest compressions for A.C.?

   A. Because the nurse has already begun chest compressions, she should remain the one doing compressions throughout BLS and ACLS.
   B. Compressions increase intrathoracic pressure and directly compress the heart, which can generate cardiac output and deliver oxygen.
   C. Because increasing the intrathoracic pressure is vital to oxygen delivery, chest recoil is unnecessary and should be avoided.
   D. Number of chest compressions given per minute has no impact on any outcomes, so pulse checks, line placements, and airways can be placed as needed without regard to interrupting chest compressions.

b. Airway
   i. For patients without an advanced airway, use the head-tilt, chin-lift technique if patients have no evidence of head or neck trauma and the jaw thrust alone if cervical spine injury is suspected (JAMA 1960;172:812-5; JACEP 1976;5:588-90) (see "Rescue Breaths" following).
   ii. Cricoid pressure is the technique of applying pressure to the victim's cricoid cartilage to push the trachea posteriorly and compress the esophagus with the goal of preventing aspiration
      (a) Recommend against use for adult cardiac arrest because of possible delay or prevention of advanced airway, lack of protection from aspiration, and lack of mastery from expert and non-expert rescuers (Emerg Med Australas 2005;17:376-81; Br J Anaesth 1994;72:47-51).
      (b) May help in visualizing vocal cords during tracheal intubation
   iii. If a foreign body airway obstruction (FBAO) occurs:
      (a) Do not act if the patient is coughing forcefully because this is a mild FBAO.
      (b) Signs of severe FBAO include a silent cough, stridor, or increasing respiratory difficulty. If these occur, ask the patient, "Are you choking?" If patients clutch their neck (universal sign of choking) or nod without answering verbally, consider severe FBAO:
         (1) Activate the emergency response system.
         (2) Administer abdominal thrusts to non-obese adults.
         (3) In obese adults or women in the late stage of pregnancy, administer chest thrusts.

(c) If the patient becomes unresponsive:
(1) Place on ground and begin CPR because chest compressions have been shown to generate higher airway pressure than abdominal thrusts (Resuscitation 2000;44:105-8).
(2) Each time the airway is opened during CPR to provide a rescue breath, look for an object in the victim's mouth and, if found, remove it. If not found, continue giving the rescue breaths, followed by 30 chest compressions.
(3) No studies have evaluated the routine use of the finger sweep to clear an airway in the absence of visible airway obstruction. Case reports have shown some efficacy, but harm has also been done in patients and rescuers. A finger sweep should not be used in the absence of visible airway obstruction.

iv. Advanced airways
(a) Supraglottic airway devices such as the laryngeal mask airway, the esophageal-tracheal Combitube, and the King airway device are considered within the scope of BLS in some districts.
(b) Will be discussed further in ACLS (following)

c. Rescue breaths
i. Primary purpose is to assist in maintaining oxygenation, with secondary purpose of eliminating carbon dioxide (CO_2).
ii. Compressions should always be initiated first because the arterial oxygen content of blood remains unchanged until CPR is initiated.
iii. Optimal compression/ventilation ratio, inspired oxygen concentration, tidal volume, and RR yet to be determined
iv. Recommended compression/ventilation ratio of 30:2 until advanced airway is placed; then ventilations at a rate of 8–10 per minute (every 6–8 seconds) after advanced airway is in place
(a) Low minute ventilation (low tidal volume and low RR) can maintain oxygenation and ventilation because of a reduced cardiac output by around 25%–33% even during chest compressions, resulting in a low oxygen uptake and CO_2 delivery (Circulation 1997;95:1635-41).
(b) Excessive ventilation can increase intrathoracic pressure and decrease venous return as well as cause gastric inflation, which can lead to aspiration and regurgitation and decrease survival (Circulation 2004;109:1960-5; Resuscitation 1998;36:71-3; JAMA 1987;257:512-5).
v. Deliver each rescue breath over 1 second. Mouth-to-mouth, mouth-to-barrier, mouth-to-stoma, and mouth-to-nose variations in initial rescue breathing are all acceptable and can produce oxygenation and ventilation (Chest 1994;106:1806-10; Br J Anaesth 1964;36:542-9).
vi. Give sufficient tidal volume to produce visible chest rise (Resuscitation 1996;31:231-4).
vii. Positive-pressure ventilation
(a) Bag-mask ventilation
(1) Components include a nonjam inlet valve, either no pressure relief valve or a pressure relief valve that can be bypassed, standard 15-mm/22-mm fittings, an oxygen reservoir to allow for high oxygen delivery, and a non-rebreathing outlet valve (Respir Care 1992;37:673-90; discussion 690-4).
(2) Should not be used by a single rescuer
(3) Should use an adult bag (1 or 2 L) and deliver (two-thirds or one-third of bag volume, respectively) about 600 mL of tidal volume, which can produce chest rise, oxygenation, and normocarbia (Resuscitation 2005;64:321-5; Resuscitation 2000;43:195-9)
(b) Supraglottic airway devices (e.g., King airway device) are considered an acceptable alternative to bag-mask ventilation during cardiac arrest (assuming proper training is supplied to rescuer) (Circ J 2009;73:490-6; Prehosp Emerg Care 1997;1:1-10).

Patient Case

2. L.S. is a 66-year-old woman visiting her husband at the hospital on the hospice unit. She is buying lunch in the cafeteria, and while in line to check out, she collapses. The emergency response team of which you are part is summoned. L.S. does not respond to voice or tapping of the shoulder, and a brief look at her chest shows no chest movement. Chest compressions are initiated while the crash cart and defibrillator are retrieved. Of note, a bag-mask ventilator is available at the scene because it is carried with the emergency response team. Which is most accurate about L.S.'s airway and breathing management?

   A. A compression/ventilation ratio of 60:1 should be used because cardiac arrest patients have minimal blood flow; therefore, oxygenation/ventilation requirements are lower.
   B. Because it is a multiple-rescuer scene, bag-mask ventilation should not be used because it is recommended only in single-rescuer resuscitations.
   C. A compression/ventilation ratio of 30:2 should be used with strict avoidance of excessive ventilation, which can decrease venous blood return to the heart.
   D. Bag-mask ventilation should not be used in any patient because advanced airways are the only way to supply oxygen and eliminate CO_2.

3. Rapid defibrillation with a manual or automated external defibrillator (AED) (Chain of Survival)
   a. Successful defibrillation is defined as 5 seconds or greater of termination of arrhythmia after a shock is delivered.
   b. Early defibrillation of VF is crucial because the most frequently witnessed out-of-hospital SCA is caused by VF, survival diminishes rapidly over time, and VF often progresses to asystole over time (Resuscitation 2000;44:7-17; (Electrical therapies; 2008;) Circulation 1997;96:3308-13).
   c. Three key actions must occur within moments of VF SCA to increase the likelihood of survival: activation of the emergency medical services system (e.g., emergency response team), provision of CPR, and shock delivery (Ann Emerg Med 1993;22:1652-8).
   d. Performing chest compressions while a defibrillator is obtained significantly improves the probability of survival (Circulation 2009;120:1241-7). When VF is present for more than a few minutes, the myocardium becomes deplete of oxygen and energy substrates.
      i. CPR can provide the oxygen and energy needed until the shock is delivered.
      ii. Increased likelihood of termination of VF from shock delivery and ROSC if CPR given first (Circulation 2004;110:10-5)
      iii. If CPR is initiated immediately, survival can double or triple at most time intervals until defibrillation occurs (Resuscitation 2000;44:7-17; Ann Emerg Med 1995;25:780-4; Ann Emerg Med 1993;22:1652-8).
   e. Early defibrillation is a powerful predicator of ROSC after VF.
      i. Survival rates are highest for VF when CPR and defibrillation occur within 3–5 minutes of the event (Circ Cardiovasc Qual Outcomes 2010;3:63-81; Resuscitation 2009;80:1253-8).
         (a) For every minute that passes after collapse, survival from VF decreases 7%–10% (Ann Emerg Med 1993;22:1652-8).
         (b) CPR prolongs VF and delays the progression to asystole (Resuscitation 2000;47:59-70; Am J Emerg Med 1985;3:114-9).
      ii. There is conflicting evidence to recommend delaying shock delivery in order to provide CPR first in VF and pulseless VT; subsequently, CPR should be initiated immediately, with shock delivery as soon as possible.

iii. One-shock biphasic (bidirectional) shock protocols are better than or equivalent to three-shock monophasic (one-directional) stacked protocols in terminating VF.
  (a) Almost all AEDs manufactured currently are biphasic.
  (b) Polyphasic waveform defibrillators are currently under investigation.
iv. With any shock delivery, chest compressions should resume immediately, and pulse check should be delayed until the end of the next cycle of CPR because this can improve defibrillation and ROSC (Circulation 2004;110:10-5; Circulation 2002;105:2270-3).
v. The optimal shock energy for biphasic first shock has yet to be determined.
  (a) Low-energy dosages (200 J or less) are safe and have equivalent or higher efficacy of termination of VF compared with monophasic waveform shocks at the same or higher energy (Circulation 2007;115:1511-7; Prehosp Emerg Care 2000;4:305-13).
  (b) The energy dosage used should be according to the manufacturer's recommendation (e.g., 120 or 200 J).
vi. If additional shocks are needed, it is recommended that at least equivalent and potentially higher energy be used.
vii. Electrode placement
  (a) Pad positioning is equally effective in terminating ventricular arrhythmias in four positions: anterolateral, anteroposterior, anterior-left infrascapular, and anterior-right infrascapular (Medicina (Kaunas) 2006;42:994-8; Physiol Meas 2006;27:1009-22).
  (b) Lateral pads should be placed under breast tissue, and hirsute men should be shaved before the placement of pads.
  (c) In patients with an implantable cardioverter-defibrillator or a pacemaker, it may be beneficial to avoid placing the pads or paddles over the device.
  (d) Do not place the pads on top of a medication patch because this can cause impedance or burning (Am J Emerg Med 1992;10:128-9).
viii. In-hospital AED use should be considered in ambulatory and unmonitored areas.

f. Pulseless VT is treated like VF.
g. Pacing is not recommended for unstable VF or pulseless VT (Circulation 2010;122:S685-705).

Patient Case

3. T.V. is a 72-year-old man with a history of chronic liver disease, hypoglycemia, and atrial fibrillation. He was admitted to your medical intensive care unit (MICU) 2 days ago for severe sepsis requiring aggressive fluid resuscitation and intravenous antibiotics. T.V. did not require vasopressors to treat his severe sepsis. On ICU day 3, T.V. develops VF on telemetry, loses consciousness, and becomes pulseless; the MICU team of which you are part is summoned for a presumed VF cardiac arrest. Pads are placed on T.V. by the time your team arrives, and the rhythm is confirmed to be VF. Which is most accurate regarding defibrillation for T.V.?

A. Three vital actions with VF can lead to increased survival if they occur rapidly: activate emergency response system, provide CPR, and deliver shock.
B. T.V. should not be defibrillated but should be paced out of the VF, if possible, because pacing is more effective for pulseless VF.
C. T.V. should not have CPR until the defibrillator is charged—especially chest compressions because they decrease the likelihood of successful defibrillation.
D. Alternative treatments such as antiarrhythmics, vasopressors, and magnesium should be tried first because there is no time-sensitive nature of VF to predict the success of defibrillation.

C. ACLS – Chain of Survival
   1. Airway control and ventilation
      a. Background
         i. During CPR, oxygen delivery to the heart and brain becomes more flow-dependent than arterial oxygen saturation–dependent (Ann Emerg Med 1990;19:1104-6).
         ii. Placement of an advanced airway in cardiac arrest should not delay CPR or defibrillation.
         iii. No studies address the optimal timing of advanced airway placement. The guiding general concept is to place the advanced airway while minimizing interruptions to chest compressions.
         iv. Conflicting evidence exists for the urgent placement of an advanced airway.
            (a) An in-hospital cardiac arrest study has shown an increased 24-hour survival in patients with an advanced airway placed within 5 minutes but no difference in ROSC (Resuscitation 2010;81:182-6); however, another study has shown a worse overall survival rate in cardiac arrest patients who required intubation (Arch Intern Med 2001;161:1751-8).
            (b) Out-of-hospital cardiac arrest studies have shown that intubation in the rural and urban setting and, more specifically intubation within 13 minutes, is associated with better survival (Med J Aust 2006;185:135-9; Prehosp Emerg Care 2004;8:394-9).
      b. Oxygen during CPR
         i. Unclear what the optimal concentration of inspired oxygen content should be during CPR
         ii. 100% inspired oxygen carries the risk of toxicity, but this toxicity has not been shown in the short-term setting of adult CPR (Resuscitation 1999;42:221-9).
         iii. Use of 100% inspired oxygen is recommended as soon as it is available to optimize arterial oxyhemoglobin content and, subsequently, delivery.
         iv. During chest compressions, air is forcefully expelled from the chest, and oxygen is drawn into the chest by passive recoil. Because the ventilation requirements are lower than normal, passive oxygen delivery is theorized to be sufficient for several minutes of initial CPR (Circulation 1994;90:3070-5), but recommendations to remove ventilation cannot be made.
      c. Bag-mask ventilation: Viable option for oxygenation and ventilation during CPR but should be provided only by multiple rescuers and trained personnel (for more details, see earlier discussion) (Circulation 2010;122:S729-767)
      d. Airway adjuncts
         i. *Cricoid pressure* should be used only in special circumstances to help visualize the vocal cords and should be relaxed, released, or adjusted if it impedes ventilation or advanced airway placement.
         ii. *Oropharyngeal airways* can be considered to help facilitate bag-mask ventilation in the unresponsive patient with no cough or gag reflex.
         iii. *Nasopharyngeal airways* can be considered in patients with airway obstruction and clenched jaw but should be used cautiously in craniofacial injury and avoided in known coagulopathy because of an increased risk of bleeding (J Trauma 2000;49:967-8; Anaesthesia 1993;48:575-80).
      e. Advanced airways
         i. Endotracheal intubation
            (a) Attempted placement by unskilled providers leads to unacceptably large periods of chest compression interruption and hypoxemia.
            (b) Benefits include keeping the airway patent, allowing for suctioning of airway, high oxygen concentration delivery, medications administration, allowing for specific tidal volume delivery, and protection from aspiration.

ii. Supraglottic airways
   (a) Do not require visualization of glottis, which allow for continuous chest compressions
   (b) Types studied during cardiac arrest include laryngeal mask airway, esophageal-tracheal tube (Combitube), and laryngeal tube (Laryngeal Tube or King LT).
      (1) Laryngeal mask airway: Compared with bag-mask ventilation, is more secure and reliable and has a lower incidence of aspiration. Easier to place than endotracheal tubes, which would allow placement when access to the patient is limited or positioning constraints are in place
      (2) Combitube: Compared with bag-mask ventilation, allows isolation of airway, more reliable ventilation, and protection from aspiration. Compared with endotracheal tubes, may be easier to train personnel, and all levels of experience can use (Prehosp Emerg Care 1997;1:1-10)
      (3) Laryngeal Tube or King LT: Potentially easier to insert compared with the Combitube but not as vigorously evaluated in the cardiac arrest population
   (c) When used by trained providers, they allow as effective oxygenation and ventilation as bag-mask ventilation and endotracheal intubation.

iii. After advanced airways are secured, proper placement should be confirmed with clinical assessment and objective measures without interruptions to chest compressions.
   (a) Physical assessments include visually inspecting chest rise bilaterally and listening to the epigastrium (breath sounds should be absent) and lung fields (should be equal and adequate).
   (b) Exhaled CO_2 or esophageal detector devices are a reasonable and objective means of confirmation if continuous waveform capnography is not readily available.
   (c) Continuous waveform capnography is the most reliable and objective way to ensure, confirm, and monitor correct endotracheal tube placement. Although not specifically studied with supraglottic airways, readings should be similar to endotracheal readings.
   (d) False-positive CO_2 detection (CO_2 detected not from ventilation) is rare, whereas false-negative CO_2 detection (no CO_2 detection when ventilation is occurring) is more common. Most common cause of false-negative CO_2 detection is a reduction in blood flow or CO_2 delivery to lungs (e.g., lack of quality chest compressions, pulmonary embolism, severe airway obstruction).

iv. Post–intubation airway management
   (a) Airway should be marked (from front of teeth/gums) and secured (with tape or commercial device), avoiding compression around the neck, which could impair venous return from brain.
   (b) Chest radiography is suggested for confirmation of location of end of endotracheal tube in relation to the carina.
   (c) Slower ventilator rates (6–12 breaths/minute) have been shown to improve hemodynamic values and short-term survival in animal models (Crit Care Med 2006;34:1444-9; Circulation 2004;109:1960-5; Resuscitation 2004;61:75-82) of cardiac arrest.

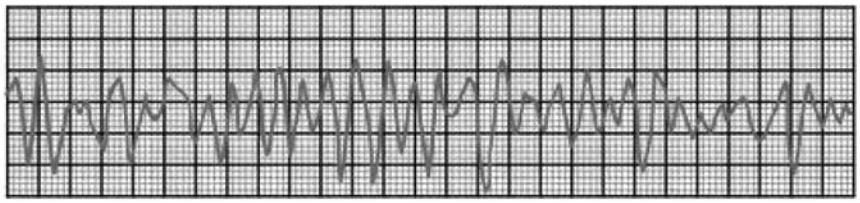
v. After placement, continuous chest compressions should be given at a rate of least 100 compressions/minute. A breath should be delivered every 6–8 seconds, making sure to avoid over-ventilation, which could decrease venous return and cardiac output.

Patient Case

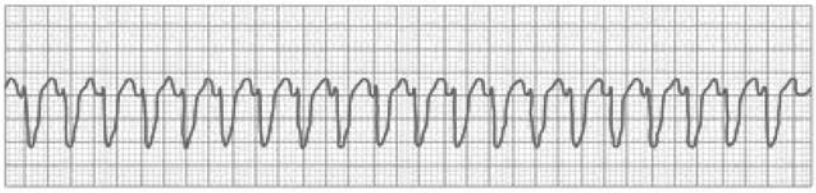
4. F.V. is a 63-year-old woman with a history of diabetes, heart failure with preserved ejection fraction, hypertension, and obstructive sleep apnea who presents to the ED with chest tightness and "feeling funny." In the ED, F.V. loses consciousness and develops pulseless VT. Chest compressions are initiated immediately, pads are placed, and bag-mask ventilation is given at a compression/ventilation ratio of 30:2. The monitor confirms the rhythm of pulseless VT. The defibrillator is charged, the patient is cleared, and the first shock is delivered. Chest compressions resume, and during the next pulse check, the patient is intubated. F.V. still does not have a pulse, and chest compressions are continued. Which is most accurate about F.V.'s resuscitation after an advanced airway is in place?

   A. After the advanced airway is in place, the compression/ventilation ratio should remain 30:2 to avoid excessive ventilation.
   B. This case was mismanaged because the advanced airway should have been placed before defibrillation and CPR for pulseless VT.
   C. The patient should be placed on room air (21% F_{IO_2} [fraction of inspired oxygen]) to avoid the proven toxicity that occurs with 100% oxygen in the cardiac arrest situation.
   D. After the advanced airway is secured, proper placement should be confirmed with clinical assessment and objective measures.

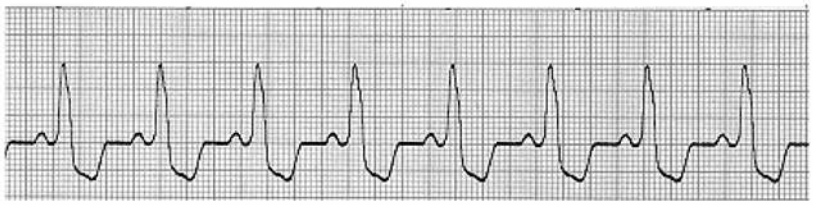
2. Management of cardiac arrest
   a. Background
      i. Cardiac arrest can be caused by four primary rhythms: VF, pulseless VT, PEA, and asystole.
      ii. These rhythms can also be classified as shockable (VF and pulseless VT) and non-shockable (PEA and asystole).
         (a) Ventricular fibrillation
            (1) Wide complex
            (2) Polymorphic
            (3) Disorganized
            (4) Coarse or fine
            (5) No/minimal forward flow



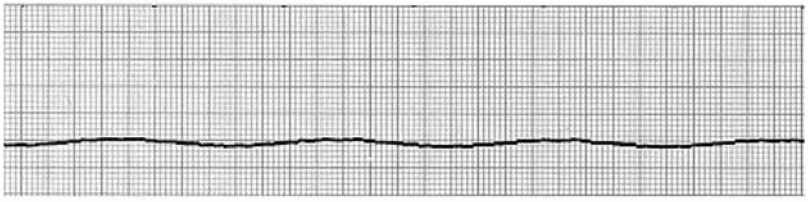
         (b) Pulseless VT
            (1) Wide complex
            (2) Monomorphic or polymorphic
            (3) Generally organized
            (4) No/minimal forward flow



(c) Pulseless electrical activity
   (1) Not a rhythm itself, but defined as an organized rhythm that would be expected to produce mechanical activity but does not
   (2) Absence or insufficient mechanical ventricular activity



(d) Asystole (ventricular asystole)
   (1) Absence of detectable ventricular electrical activity
   (2) Accompanied by absence of ventricular mechanical activity



iii. Survival requires both BLS and ACLS. Foundation of ACLS is high-quality BLS. In addition to CPR, the only proven rhythm-specific therapy that increases survival at hospital discharge is defibrillation of VF/pulseless VT.
iv. Medications and advanced airways have not been shown to increase survival of cardiac arrest but have been shown to increase the ROSC (exception: amiodarone in out-of-hospital arrest [see text that follows]) (Resuscitation 2010;81:182-6; Med J Aust 2006;185:135-9; Resuscitation 2000; 45:161-6; N Engl J Med 1999;341:871-8).
   (a) Vascular access and medication delivery should never interrupt CPR and/or defibrillation. All other therapies are "considerations" and should never compromise chest compressions.
   (b) Interruptions in chest compressions should occur only for brief rhythm assessment, shocking of VF/VT, pulse check when an organized rhythm is detected, and advanced airway placement.
v. During cardiac arrest treatment, it is imperative to evaluate, treat, and/or reverse any treatable causes of cardiac arrest (Table 1).
vi. Post–cardiac care should begin immediately after ROSC is obtained to avoid re-arrest.

Table 1. Treatable Causes of Cardiac Arrest

H's	T's
Hypoxia	Toxins
Hypovolemia	Tamponade (cardiac)
Hydrogen ion (acidosis)	Thrombosis • Pulmonary embolism • Coronary thrombosis
Hypoglycemia	
Hypo/hyperkalemia	Tension pneumothorax
Hypothermia	

Patient Case

5. V.B., a 62-year-old man with an unknown medical history, comes to your ED altered and incoherent. He is admitted to the ED for observation, where he suddenly becomes unconscious and pulseless. The ED staff, of which you are part, immediately initiates CPR for V.B. Which statement is best regarding V.B.'s cardiac arrest?
   A. Survival from V.B.'s cardiac arrest is solely dependent on medications and advanced airways. Therefore, V.B. should have CPR discontinued so that lines can be placed immediately for medication administration, and V.B. should be intubated before resuming CPR.
   B. The treatable causes of V.B.'s cardiac arrest should be reviewed and addressed. Laboratory tests should be done as able during/after, or if known, they should be reviewed during CPR to address these causes.
   C. If V.B. is in a shockable rhythm (e.g., PEA or asystole), pads should be placed, the patient cleared, and shock delivered immediately.
   D. No strategies are in place for care after V.B.'s arrest to avoid re-arrest or improve outcomes from the cardiac arrest.

b. Medication background (rhythm-independent)
   i. Goal: Increase myocardial blood flow during CPR and help achieve ROSC
   ii. Drug delivery
      (a) Central intravenous administration is recommended, if available. Central line placement should not interrupt CPR. The advantage of central administration is higher peak and shorter drug circulation times compared with peripheral routes (Crit Care Med 1988;16:1138-41; Ann Emerg Med 1981;10:73-8; Ann Emerg Med 1981;10:417-9).
      (b) If peripheral administration of medications is necessitated, the bolus injection should be followed by a 20-mL bolus of an intravenous fluid (e.g., 0.9% sodium chloride) to facilitate drug flow from the extremity to the central circulation (Am J Emerg Med 1990;8:190-3).
      (c) If proximal humerus intraossesous access is used, administration and drug delivery are similar to central venous access. If proximal or distal tibial intraosseous access in used, administration and drug delivery are similar to peripheral venous access.
      (d) Endotracheal (ET) delivery
         (1) NAVEL acronym summarizes medications that have been studied and shown to have tracheal absorption by ET tube delivery. N – naloxone, A – atropine, V – vasopressin, E – epinephrine, L – lidocaine
         (2) Serum concentrations of medications are less when given by ET delivery.

(3) Optimal ET dose unknown; typically, it is 2–2.5 times the intravenous dose but may be higher (e.g., up to 3–10 higher for epinephrine) (Crit Care Med 1987;15:1037-9)
(4) Should be diluted with either 5–10 mL of 0.9% sodium chloride or sterile water and injected directly into the ET tube (Crit Care Med 1994;22:1174-80)

(e) Peak effect of intravenous or intraosseous medication delayed 1–2 minutes during CPR
(f) Theoretical concern that giving high-dose bolus vasopressors after ROSC following defibrillation may precipitate cardiac instability and re-arrest. May be avoided by using physiologic monitoring such as quantitative waveform capnography, intra-arterial pressure monitoring, or continuous central venous oxygen saturation monitoring and avoiding administration if ROSC occurs (J Emerg Med 2009;38:614-21; Ann Emerg Med 1992;21:1094-101; Ann Emerg Med 1990;19:1104-6)

Patient Case

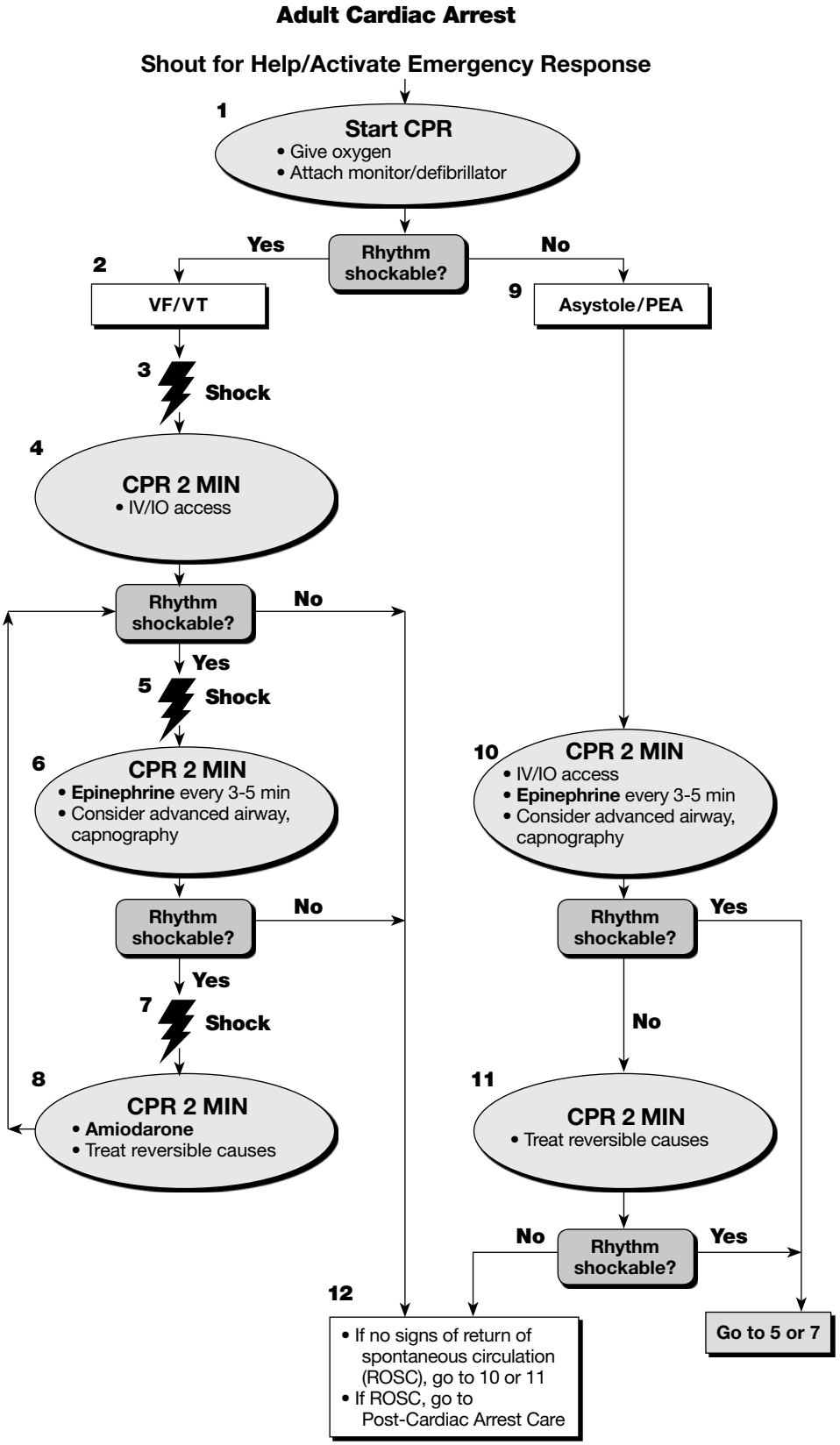
6. M.G., a 58-year-old woman with a history of chronic osteoarthritis and peptic ulcer disease, is admitted to the MICU with hypovolemic shock caused by a suspected bleeding gastric ulcer. Endoscopy is performed, confirming the gastric ulceration. The ulcer is cauterized, and M.G. is stabilized. On ICU day 2, M.G. becomes lethargic, hypoxic, and subsequently pulseless. The MICU team is summoned, and the monitor reveals VF. Which general principles are most accurate regarding the medication management of M.G.'s VF arrest?

A. Endotracheal delivery is preferred because all cardiac arrest medications can be delivered by the endotracheal route.
B. Peripheral administration is preferred because the peak concentrations are higher and the circulation time is shorter compared with other routes.
C. Intraosseous administration is preferred because administration and dosing are similar to that for the endotracheal route.
D. Central administration is preferred because dosing is easier and circulation time of cardiac arrest medications is shorter.

c. Management of VF/pulseless VT (Figure 1): Defibrillation (summary, details available above in the Chain of Survival: defibrillation section)
   i. When VF/pulseless VT detected, CPR should continue until defibrillator (either manual or automatic) charging period is over
   ii. It is strongly recommended that CPR be performed while the defibrillator is readied because chest compressions can delivery oxygen and potentially unload the ventricles, increasing the likelihood that a perfusing rhythm will return after shock is delivered.
   iii. Because intentionally delaying defibrillation for CPR has mixed results, it cannot currently be recommended.
   iv. Once defibrillator is charged, patient is "cleared."
   v. Shock is delivered, and CPR is immediately resumed, beginning with chest compressions.
      (a) Pulse check is delayed until 2 minutes of CPR is given.
      (b) Pause for rhythm and pulse check; continue CPR, if necessary.
   vi. If biphasic defibrillator is available:
      (a) Provider should use manufacturer's recommended energy dose (e.g., 120–200 J).
      (b) If information unavailable, the maximum dosing can be considered
      (c) Second and subsequent defibrillator energy dosages should be equivalent, and consideration should be made for escalating energy doses, if possible.

vii. If monophasic defibrillator is available:
  (a) Initial energy dose should be 360 J.
  (b) Second and subsequent defibrillator energy dosages should be 360 J.
viii. If VF/pulseless VT is terminated by defibrillation and reoccurs, resulting in an arrest, the successful energy dosage used previously should be employed.
ix. Change of multimodal defibrillator from automatic to manual mode may result in fewer interruptions of CPR but also an increased frequency of inappropriate shocks (Resuscitation 2007;73:131-6; Resuscitation 2007;73:212-20).

d. Medication therapy for VF/pulseless VT
  i. Consider medication therapy after one shock and 2 minutes of CPR (one cycle). The optimal timing of medication administration is unclear.
  ii. Vasopressors:
    (a) First-line medications include epinephrine or vasopressin (Figure 1; Table 2).
    (b) No other vasopressors (e.g., phenylephrine or norepinephrine) have shown any benefit compared with epinephrine (JAMA 1992;268:2667-72; Acta Anaesthesiol Scand 1985;29:610-3).
    (c) Adding methylprednisolone and vasopressin to epinephrine during ACLS plus stress dose hydrocortisone for post-ROSC shock compared with placebo may aid in the ROSC during cardiac arrest and improve discharge neurologic function in patients who survive. Role of steroids may be debated, given the addition of vasopressin in the study arm (JAMA 2013;310:270-9).
  iii. Antiarrhythmics:
    (a) No evidence that, in cardiac arrest, any antiarrhythmics increase survival to discharge
    (b) Amiodarone (Table 2) increases survival to hospital admission in out-of-hospital arrest compared with placebo and lidocaine (N Engl J Med 2002;346:884-90; N Engl J Med 1999;341:871-8).
      (1) Should be considered for refractory (unresponsive to shock, CPR, and a vasopressor) VF/pulseless VT
      (2) Administered as intravenous/intraosseous push if pulseless. If pulse is obtained, must be given as slow intravenous piggyback
      (3) Hemodynamic effects of bradycardia and hypotension may be partly related to vasoactive solvents (polysorbate 80 and benzyl alcohol) (Am J Cardiol 2002;90:853-9).
    (c) Lidocaine has no proven short- or long-term efficacy in cardiac arrest, but it can be considered if amiodarone is unavailable (Table 2).
    (d) Magnesium sulfate (Table 2) is effective for cardiac arrest caused by torsades de pointes (i.e., caused by early afterdepolarizations during phase 2 of the action potential).
      (1) Not effective when VF/pulseless VT is not associated with torsades de pointes
      (2) May consider for emergency magnesium replacement in patients who sustain cardiac arrest and are hypomagnesemic
      (3) Optimal dosing has not been established.



CPR Quality
- Push hard (≥2 inches [5 cm]) and fast (≥100/min) and allow complete chest recoil
- Minimize interruptions in compressions
- Avoid excessive ventilation
- Rotate compressor every 2 minutes
- If no advanced airway, 30:2 compression-ventilation ratio
- Quantitative waveform capnography
  - If $PETCO_2$ <10 mm Hg, attempt to improve CPR quality
- Intra-arterial pressure
  - If relaxation phase (diastolic) pressure <20 mm Hg, attempt to improve CPR quality

Return of Spontaneous Circulation (ROSC)
- Pulse and blood pressure
- Aburpt sustained increase in $PETCO_2$ (typically ≥40 mm Hg)
- Spontaneous arterial pressure waves with intra-arterial monitoring

Shock Energy
- **Biphasic:** Manufacturer recommendation (eg, initial dose of 120-200 J); if unknown, use maximum available. Second and subsequent doses should be equivalent, and higher doses may be considered.
- **Monophasic:** 360 J

Drug Therapy
- **Epinephrine IV/IO Dose:** 1 mg every 3-5 minutes
- **Vasopressin IV/IO Dose:** 40 units can replace first or second dose of epinephrine
- **Amiodarone IV/IO Dose:** First dose: 300 mg bolus. Second dose: 150 mg.

Advanced Airway
- Supraglottic advanced airway or endotracheal intubation
- Waveform capnography to confirm and monitor ET tube placement
- 8-10 breaths per minute with continuous chest compressions

Reversible Causes
- —**H**ypovolemia
- —**H**ypoxia
- —**H**ydrogen ion (acidosis)
- —**H**ypo-/hyperkalemia
- —**H**ypothermia
- —**T**ension pneumothorax
- —**T**amponade, cardiac
- —**T**oxins
- —**T**hrombosis, pulmonary
- —**T**hrombosis, coronary

Figure 1. Adult cardiac arrest algorithm.

Table 2. Medications Used During Sudden Cardiac Arrest

Medication	Primary Mechanism of Action in Cardiac Arrest	Dosage, Route, Frequency	Clinical Benefits
Epinephrine (N Engl J Med 1992;327:1045-50; Circulation 1984;69:822-35; Crit Care Med 1979;7:293-6)	α-Adrenergic agonist effects leading to vasoconstriction	1 mg IV/IO q3–5 min 2–2.5 mg ET q3–5 min	Increases coronary and cerebral perfusion pressure during CPR Increases ROSC
Vasopressin (Arch Intern Med 2005;165:17-24; N Engl J Med 2004;350:105-13; Lancet 2001;358:105-9)	Nonadrenergic vasoconstrictor (vasopressin-1 receptor mediated)	40 units IV/IO x 1 (can replace epinephrine as either the first or second dose)	No difference in ROSC, neurologic recovery, or survival to discharge compared with epinephrine
Amiodarone (N Engl J Med 2002;346:884-90; N Engl J Med 1999;341:871-8)	$Na^+/K^+/Ca^{2+}$ channel and β-receptor antagonist	First dose: 300 mg or 5 mg/kg IV/IO x 1 Second dose: 150 mg IV/IO x 1 Max: 2.2 g/day	Increases survival to hospital admission compared with lidocaine or placebo for VF/pulseless VT arrest
Lidocaine (Resuscitation 1997;33:199-205)	Na^+ channel antagonist	First dose: 1–1.5 mg/kg IV/IO x 1 Subsequent dosing: 0.5–0.75 mg/kg q5–10 min Max 3-mg/kg cumulative dose	Increases ROSC and possibly survival to admission for out-of-hospital VF cardiac arrest. No improvement in overall or discharge survival Insufficient evidence to recommend for refractory VF/pulseless VT unless amiodarone unavailable
Magnesium (Clin Cardiol 1993;16:768-74; New Trends Arrhythmias 1991;7:437-42; Circulation 1988;77:392-7)	Stops EAD in torsades de pointes by inhibiting Ca^{2+} channel influx	1–2 g diluted in 10 mL of 5% dextrose or sterile water IV/IO x 1	Can aid in stopping torsades de pointes in patients with prolonged QT interval

EAD = early afterdepolarization; ET = endotracheal; IO = intraosseously; IV = intravenously; min = minute; q = every.

e. Management of PEA/asystole
   i. CPR and treatment of reversible causes are vital to treatment of PEA/asystole.
   ii. Medication therapy
      (a) Vasopressors (e.g., epinephrine and vasopressin) can be given as soon as feasible (Table 2).
      (b) Atropine has been removed from the algorithm because of its lack of therapeutic benefit.

f. Role in treating reversible causes
   i. Echocardiography may be helpful, if available, in the management of PEA to help differentiate the following (Am J Cardiol 1992;70:1056-60):
      (a) Intravascular volume status (ventricular volume)
      (b) Cardiac tamponade
      (c) Massive pulmonary embolism (right ventricular size, function)
      (d) Mass lesions (tumor, clot)
      (e) Coronary thrombosis (right and left ventricular function, regional wall motion abnormalities)
   ii. Because hypoxia often causes of PEA arrest, more focused attention may be given to placement of airway and oxygen delivery.
   iii. Please see the specific chapters for pulmonary disorders (massive pulmonary embolism and tension pneumothorax), cardiology (acute myocardial infarction and cardiac tamponade), shock (hypovolemic shock and oxygen delivery), acid-base disorders (acidemia), endocrinologic disorders (hypoglycemia), and electrolytes (hypo/hyperkalemia).

g. Interventions to avoid in cardiac arrest
   i. Sodium bicarbonate
      (a) Tissue acidosis and acidemia result during cardiac arrest for several reasons, including inadequate or absent blood flow, arterial hypoxia, or underlying pathophysiology.
      (b) Mainstays of restoring acid-base status include high-quality chest compressions and appropriate ventilation/oxygenation.
      (c) Conflicting evidence exists for the use of sodium bicarbonate, with most data showing no benefit or poor outcome with use (Ann Emerg Med 1998;32:544-53; Resuscitation 1995;29:89-95; Am J Emerg Med 1992;10:4-7; Chest 1990;97:413-9; Resuscitation 1989;17(suppl):S161-172; discussion S199-206).
      (d) Detrimental effects may be associated with sodium bicarbonate in cardiac arrest, including:
         (1) Compromised coronary perfusion pressure by reducing systemic vascular resistance (JAMA 1991;266:2121-6)
         (2) Shifting the oxyhemoglobin dissociation curve to the left by creating an extracellular alkalosis and decreased release of oxygen
         (3) Causing hypernatremia and subsequent hyperosmolarity
         (4) Producing excess CO_2 through rapid dissociation, which can freely diffuse intracellularly (e.g., myocardial and cerebral cells) and cause intracellular acidosis (Science 1985;227:754-6)
         (5) Inactivation of concurrently administered catecholamines (e.g., epinephrine) (Hosp Pharm 1969;4:14-22)
      (e) Certain circumstances may warrant sodium bicarbonate use such as tricyclic antidepressant overdose, bicarbonate-wasting causes of metabolic acidosis, and hyperkalemia. Initial dosage should usually be 1 mg/kg intravenous push with monitoring of clinical status, bicarbonate concentration, laboratory values, and blood gas analysis.
   ii. Calcium
      (a) No trial has established any impact on survival in either in- or out-of-hospital cardiac arrest (Ann Emerg Med 1985;14:626-9; Ann Emerg Med 1985;14:630-2).
      (b) Consider in patients with preexisting hypocalcemia and signs and symptoms of acute hypocalcemia (e.g., severe tetany or seizures).

iii. Atropine
(a) No prospective studies have evaluated atropine for bradycardic PEA or asystolic cardiac arrest.
(b) Conflicting results exist from retrospective analyses and case reports (Acta Anaesthesiol Scand 2000;44:48-52; Ann Emerg Med 1984;13:815-7; Ann Emerg Med 1981;10:462-7).
(c) Atropine has not been associated with harm in treating bradycardic PEA or asystolic cardiac arrest, but because of the lack of convincing evidence of benefit, it is no longer recommended for cardiac arrest.
iv. Intravenous fluids
(a) Normothermic, hypertonic, and chilled fluids have been evaluated in animal models and small human studies, with no survival benefit.
(b) If hypovolemic shock is the suspected cause of the cardiac arrest, fluid resuscitation should be initiated immediately.
v. For indications of fibrinolysis for cardiac arrest, please see the pulmonary chapter for treatment of pulmonary embolism and the cardiology chapter for treatment of acute myocardial infarction.
vi. Pacing
(a) Transcutaneous, transvenous, and transmyocardial pacing not beneficial in cardiac arrest and does not improve ROSC or survival
(b) Not recommended for routine use in cardiac arrest

h. For information on acute symptomatic arrhythmias (bradycardias and tachycardias), see the cardiology chapter.

D. Post–Cardiac Arrest Care – Chain of Survival: Objectives of post–cardiac arrest care can be divided into initial and subsequent (Circulation 2010;122:S768-786; Circulation 2008;118:2452-83).
1. Initial
a. Optimize hemodynamics: Target MAP 65–100 mm Hg or greater, central venous pressure 8–12 mm Hg, central venous oxygen saturation greater than 70%, urine output greater than 1 mL/kg/hour, and normal serum lactate
i. Consider the patient's normal BP, cause of arrest, and severity of myocardial dysfunction for all values above.
ii. Use intravenous crystalloids and colloids, continuous vasopressors and inotropes, transfusions, and renal replacement as needed to meet target goals.
b. Transfer patient (out-of-hospital arrest) to a system or unit (in-hospital arrest) that can provide advanced post–cardiac arrest care, including continuous electrocardiographic (ECG) monitoring with immediate 12-lead ECG, central intravenous access if possible, coronary reperfusion, and/or therapeutic hypothermia.
c. Try to identify and treat the reversible causes of cardiac arrest (Table 1). Laboratory and diagnostic tests should be performed to aid in identifying a potential underlying cause.
2. Subsequent
a. Consider therapeutic hypothermia and body temperature regulation. Should be considered for any patient with ROSC who does not follow commands (i.e., comatose) after cardiac arrest. Best evidence exists for out-of-hospital VF/pulseless VT cardiac arrest, but it should be considered for all types and locations of cardiac arrest (Circulation 2010;122:S768-786)
i. Only intervention that has been shown to improve neurologic recovery after SCA
ii. Optimal targets, timing, duration, and other variables still unclear:
(a) Goal target body temperature 32°C–34°C (N Engl J Med 2002;346:549-56; N Engl J Med 2002;346:557-63), though targeting 36°C instead of 33°C may be equivocal (N Engl J Med 2013;369:2197-206)

(b) Duration of at least 12 hours; optimally, a minimum of 24 hours
(c) Initiation of therapeutic hypothermia as soon as possible, within 2 hours, if possible, with goal temperature attainment within 6–8 hours; however, several retrospective studies have
not confirmed the timing of initiation or the timing of temperature attainment as predictors
of neurologic outcome (Acta Anaesthesiol Scand 2009;53:962-34; Int J Cardiol 2009;133:223-8)
(d) Modality for cooling includes feedback-controlled endovascular systems, surface-cooling devices, ice packs/bags, cooling blankets, and/or iced isotonic fluids.
(e) Axillary or oral temperature monitoring is inadequate for therapeutic hypothermia (Acta Anaesthesiol Scand 1998;42:1222-6; J Cardiothorac Vasc Anesth 1996;10:336-41) and requires esophageal, bladder (avoid in anuric patients), or pulmonary artery temperature monitoring. Ideally, the monitoring modality chosen will be used for other indications as well.

iii. Major complications of therapeutic hypothermia (Table 3)

Table 3. Major Organ-Specific Complications of Therapeutic Hypothermia

Musculoskeletal (N Engl J Med 2013;369:2197-206; Anesthesiology 2009;111:110-5; Br J Anaesth 2005;94:756-62; N Engl J Med 2002;346:549-56; N Engl J Med 2002;346:557-63; JAMA 1997;277:1127-34; Am J Physiol 1960;198:481-6)	**Shivering:** A. Body's natural response to hypothermia, preceded by arteriovenous vasoconstriction. Can increase metabolic heat production by 600%, thereby slowing the induction of hypothermia 1. Typically slows or stops at core temperatures < 34°C 2. Continuous or as-needed paralytics can be used for prevention and treatment of shivering (see the chapter on management of paralytics for appropriate selection and dosing of agent[s]) i. Hypothermia decreases clearance and prolongs the duration of neuromuscular-blockade (see Table 4 for examples) ii. Train-of-four is not a reliable method of monitoring during hypothermia; clinical monitoring or continuous EEG (electroencephalography) may be warranted 3. Agents that decrease the shivering threshold: i. Scheduled acetaminophen 650 mg q4–6 hr or buspirone 30 mg q12 hr as alternatives to paralysis may reduce the shivering threshold ii. Magnesium sulfate also reduces the shivering threshold, and administration during the induction phase of hypothermia can be considered iii. Meperidine decreases the shivering threshold but should be avoided because of decreased effective glomerular filtration rate (GFR) during hypothermia and subsequent increased risk of seizures when meperidine is used in patients with decreased GFR iv. Dexmedetomidine and clonidine also decrease the shivering threshold, but extreme caution should be used because of the hypotensive and bradycardic effects of both agents

Table 3. Major Organ-Specific Complications of Therapeutic Hypothermia *(continued)*

Neurologic (Circulation 2010;122:S729-767; Circulation 2008;118:2452-83; Pharmacotherapy 2008;28:102-11)]	**Sedation and Analgesia:** A. Adequate pain control and sedation must be employed B. Target Richmond Agitation and Sedation Scale score of -3 to -5 (see chapter on sedation for agent selection and dosing) during hypothermia C. Accumulation of parent and active metabolites can be expected for each analgesic and sedative, which lead to prolonged sedation and potentially untoward adverse effects (see Table 4 for examples) **Seizures:** A. Possible complications of cardiac arrest and therapeutic hypothermia B. Consider benzodiazepines as first line to break seizures C. Phenytoin, barbiturates, valproic acid, and propofol can all be used, with vigilant monitoring of adverse effects because of decreased clearance (see Table 4 for examples; for dosing and monitoring values, see the Status Epilepticus chapter)
Cardiac (Heart Lung 2001;30:161-3; Int Anesthesiol Clin 1964;2:803-27)	**Arrhythmias:** A. Include VT, VF, and atrial fibrillation B. If life threatening, should consider discontinuing therapeutic hypothermia and active rewarming C. Sinus bradycardia is common and, in isolation, should not be treated unless it leads to hemodynamic instability (hypotension or organ dysfunction) **Electrocardiography observations:** A. Prolonged PR, QRS, and QT intervals B. Caution should be exercised when using medications that prolong the QT interval **Hemodynamics:** A. Decreased cardiac output
Hepatobiliary (Pharmacotherapy 2008;28:102-11; Ther Drug Monit 2001;23:192-7; Anesthesiology 2000;92:84-93; Clin Pharmacol Ther 1979;25:1-7)	A. Elevated transaminases B. Reduced activity of non-cytochrome and cytochrome P450–mediated metabolism C. See Table 4 for examples of metabolic changes in selected medications during hypothermia
Endocrinologic (N Engl J Med 2002;346:557-63; Endocrinology 1970;87:750-5)	A. Hyperglycemia caused by a decreased insulin production and effect in periphery, increased gluconeogenesis, and glycogenolysis B. Continuous insulin infusions may be necessary for glucose control. Goal should be < 180 mg/dL without inducing hypoglycemia
Renal (Resuscitation 2004;60:253-61; J Neurosurg 2001;94:697-705)	A. Decreased effective glomerular filtration (urine output may increase because of cold diuresis, but not effective) B. Electrolyte loss (K^+, PO_4^{3-}, Na^+, Ca^{2+}) during cooling phase; caution when replacing during rewarming phase
Hematologic (Pharmacotherapy 2008;28:102-11; Bri J Haematol 1999;104:64-8; Crit Care med 1992;20:1402-5)	A. Coagulopathy caused by thrombocytopenia, impaired activation and activity of clotting factors, impaired platelet function B. Actively bleeding patients should not be cooled

hr = hour(s).

Table 4. Pharmacokinetic and Pharmacodynamic Changes of Selected Medications During Hypothermia

Fentanyl	Plasma concentration increases by 25% with a 3.7-fold decrease in clearance
Morphine	Receptor affinity (μ) decreased as temperature decreases
Propofol	Plasma concentration increases by 28%; decreased clearance
Midazolam	Clearance decreases by about 11% per degree Celsius below 36.5°C
Rocuronium	Decreased clearance by 50%, increased duration of action 2-fold
Vecuronium	Decreased clearance by 11% per degree Celsius; increased duration of action 2-fold
Cisatracurium	Eliminated by Hofmann elimination, which is a temperature-dependent enzymatic process; anticipate prolonged activity
Phenytoin	AUC (area under the concentration-time curve) increased by 180%; clearance and elimination rate constant decrease by 50%

nformation from: Pharmacotherapy 2008;28:102-11; Ther Drug Monit 2001;233: 192-7; Anesthesiology 2000;92:84-93; Br J Haematol 1999;104:68-8; Eur J Anaesthesiol Suppl 1995;1:95-106; Cllin Pharmacol Ther 1979;25:1-7).

iv. Rewarming should be a passive process over 8 hours (around .33°C–0.5°C per hour) (Acta Anaesthesiol Scand 2009;53:926-34; N Engl J Med 2002;346:557-63; N Engl J Med 2002;346:549-56).

b. Identify and treat acute coronary syndromes.
   i. Cardiovascular disease and acute coronary ischemia are the most common causes of cardiac arrest (Am Heart J 2009;157:312-8; N Engl J Med 1997;336:1629-33).
   ii. Consideration of treatment of acute coronary syndromes should not be deferred in patients who are comatose or when therapeutic hypothermia is used.
   iii. See the Cardiology chapter for the workup and treatment of acute coronary syndromes.

c. Optimize mechanical ventilation.
   i. Goal arterial oxygen saturation is 94% or greater.
   ii. Avoid hyperventilation or over-bagging to avoid increase in intrathoracic pressure and decrease in cardiac output.
   iii. Goal $Paco_2$ is 40–45 mm Hg or $PETCO_2$ 35–40 mm Hg.

d. Support organ systems
   i. Vasopressor/inotropes to support end-organ perfusion (see Table 5)
      (a) Adrenergic medications should not be administered with alkaline solutions or sodium bicarbonate because they are inactivated (Hosp Pharm 1969;4:14-22).
      (b) Central line is recommended because any agent with α-agonist properties can lead to extravasation and tissue necrosis.

Table 5. Common Vasoactive Agents Used After Cardiac Arrest[a]

Medication	Typical Dosing Range (mcg/kg/minute)	Clinical Pearls
Epinephrine	0.03–0.3	• Mixed α and β activity • Used to treat severe hypotension (e.g., SBP < 70 mm Hg) • Used for symptomatic bradycardia • Used for hemodynamically unstable anaphylactic reactions
Norepinephrine	0.03–0.3	• α- > β-receptor activity • Used to treat severe hypotension (e.g., SBP < 70 mm Hg) • Should be used in volume-resuscitated patients • Currently first line for septic shock

Table 5. Common Vasoactive Agents Used After Cardiac Arrest[a] *(continued)*

Medication	Typical Dosing Range (mcg/kg/minute)	Clinical Pearls
Phenylephrine	0.3–3	• Pure α agonist • Used to treat severe hypotension (e.g., SBP < 70 mm Hg) • Should be used in volume-resuscitated patients
Dopamine	2–20	• Dose-related receptor activity: 2–5 mcg/kg/minute dopamine receptor, 5–10 mcg/kg/minute β_1-receptor, > 10 α_1-receptor • Does not provide exclusive receptor activity across dosing ranges • Use cautiously in patients with a history of heart disease or arrhythmias • Useful for patients with bradycardia and hypotension
Dobutamine	2–20	• Predominance of inotropic properties but with activity on β_1-, β_2-, and α_1-receptor • Used to treat low cardiac output • α_1-agonist and β_2-agonist counterbalance, leading to little change in systemic vascular resistance • Can lead to vasodilation at higher doses or in select patients • Less systemic or pulmonary vasodilation than milrinone • More tachycardia than milrinone • Use cautiously in patients with a history of heart disease or arrhythmias
Milrinone	0.25–0.5	• Phosphodiesterase type 3 inhibitor • Used to treat low cardiac output • Longer onset of activity, which may warrant loading dose. Caution should be used with loading dose because of significant systemic hypotension • Longer duration of activity than dobutamine • Accumulates in renal dysfunction • More systemic and pulmonary vasodilation than dobutamine • Less tachycardia than dobutamine

[a]See chapter on shock for a detailed discussion regarding selection of agent, dosing, pharmacology, and clinical considerations.

ii. Glucose management (Circulation 2010;122:S768-786; Circulation 2008;118:2452-83)
   (a) Avoidance of severe hypoglycemia (40 mg/dL or less)
   (b) Target moderate glucose control: 144–180 mg/dL
   (c) May require continuous insulin infusion to maintain above goals
   (d) Seizure control/prevention (Neurology 1988;38:401-5; JAMA 1985;253:1420-6): Seizures, myoclonus, or both occur in 5%–15% of adult patients who achieve ROSC and is more frequent in those who remain comatose.
   (e) Seizures, myoclonus, or both occur in 5%–15% of adult patients who achieve ROSC and is more frequent in those who remain comatose.
      (1) Clonazepam, valproic acid, and levetiracetam are all effective for myoclonus, but clonazepam should be considered first line.
      (2) Benzodiazepines, phenytoin, valproic acid, propofol, and barbiturates are all effective for post–cardiac arrest seizures.
      (3) For dosing and monitoring parameters, see the Status Epilepticus chapter.

iii. Renal dysfunction: The indications for initiating renal replacement therapy in cardiac arrest survivors are the same as in critically ill patients in general (Lancet 2005;365:417-30).

e. Assess prognosis.
   i. Brain injury and cardiovascular instability are the major determinants of survival after cardiac arrest (Intensive Care Med 2004;30:2126-8).
   ii. If therapeutic hypothermia is considered, a delay of 72 hours after rewarming should be implemented for withdrawal of care.
   iii. If therapeutic hypothermia is not considered, several different variables have predicted outcomes at 24 hours and for up to 72 hours. No clinical neurologic signs have reliably predicted poor neurologic outcomes less than 24 hours after cardiac arrest (Neurology 2006;66:62-8; Crit Care Med 1987;15:820-5).
   iv. Prudent to perform any prognostication after removal of opioids, sedatives, paralytics, and so forth
f. Assist survivors with rehabilitation needs.

Patient Case

7. K.G., a 71-year-old woman with a history of atrial fibrillation, coronary artery disease after three-vessel coronary bypass artery grafting 6 years ago, diabetes, and osteoarthritis, is being admitted to your MICU for therapeutic hypothermia after PEA arrest and subsequent ROSC. K.G., who remained comatose after the ROSC, was intubated; she is hemodynamically stable (BP 94/72 mm Hg and HR 86 beats/minute). Which is most accurate regarding targeted temperature management (therapeutic hypothermia) for K.G.?
   A. K.G. may experience hypoglycemia because this is a common complication and may require continuous dextrose 10% in water or dextrose 20% in water infusions.
   B. Dose modifications or medication avoidance for cytochrome P450–metabolized medications should occur for K.G. during therapeutic hypothermia, given reduced enzymatic activity.
   C. The optimal duration of K.G.'s therapeutic hypothermia should be at least 72 hours to affect survival.
   D. Temperature targets should be 28°C–30°C to improve the neurologic recovery.

II. HYPERTENSIVE CRISIS

A. Definitions (Cardiol Clin 2012;30:533-43; Chest 2007;131:1949-62; Cardiol Clin 2006;24:135-46):
   1. Hypertensive urgency: A systolic blood pressure (SBP) of 180 mm Hg or greater and/or a diastolic blood pressure (DBP) of 110 mm Hg or greater without evidence of target organ damage
   2. Hypertensive emergency: Presence of an abrupt significantly elevated BP (often defined as SBP greater than 200 mm Hg and/or DBP greater than 120 mm Hg) with concurrent target organ dysfunction (e.g., acute kidney injury/failure, heart failure exacerbation, obtundation). Table 6 lists example conditions that, when accompanied by high BP, define hypertensive emergency.
   3. MAP: Average pressure in the arteries experienced over one cardiac cycle. Calculated by MAP = 1/3 SBP + 2/3 DBP

Table 6. Examples of Acute Target Organ Damage and Clinical Presentations

Eclampsia, preeclampsia	Hypertensive encephalopathy
Acute kidney injury/failure	Acute shortness of breath, flash pulmonary edema, or acute left ventricular dysfunction
Acute aortic dissection (type A or B)	Acute intracranial bleeding (nontraumatic)
Seizures	Acute myocardial ischemia/infarction
Retinopathy	Cerebral infarction

B. Less than 1% of patients with hypertension will experience a hypertensive crisis (Acta Med Scand Suppl 1981;650:1-62).

C. 10-year survival approaches 70% (Int J Med 1993;96:485-93), with 1-year survival greater than 90%.

D. Common Causes (Cardiol Clin 2012;30:533-43; Cardiol Clin 2006;24:135-46):
   1. Intoxications – Cocaine, amphetamines, phencyclidine hydrochloride, stimulant diet pills
   2. Nonadherence to antihypertensive regimen
   3. Withdrawal syndromes – Clonidine or β-antagonists
   4. Drug-drug/drug-food interactions (e.g., monoamine oxidase inhibitors and tricyclic antidepressants, antihistamines, or tyramine)
   5. Spinal cord disorders
   6. Pheochromocytoma
   7. Pregnancy

E. Management:
   1. Hypertensive urgency: Lower BP slowly over 24–48 hours using oral medications (often, home regimen reinitiation). Does not require an ICU admission for treatment
   2. Hypertensive emergency: Requires ICU monitoring and intravenous medications. See goals listed in Table 7.

Table 7. Timeframe for BP Lowering with Hypertensive Emergency[a]

Goal time	BP target
< 60 min	↓ DBP by 10%–15% or MAP by 25% with goal DBP ≥ 100 mm Hg
2–6 hr	SBP 160 mm Hg and/or DBP 100–110 mm Hg
6–24 hr	Keep above BP goals (hours 2–6) during first 24 hours
24–48 hr	Outpatient BP targets

[a]See exceptions to these goals in the text that follows.

   a. A 25% reduction in MAP over the first hour is targeted in order to maintain cerebral perfusion (blood flow autoregulation) and not to precipitate ischemia, which has been found with 50% reductions (Stroke 1984;15:413-6).
   b. If neurologic function deterioriates during the initial 25% decrease (or during subsequent lowering), therapy should be discontinued (N Engl J Med 1990;323:1177-83).
   c. Exceptions exist regarding the timing and BP goals listed earlier:
      i. Acute aortic dissection
         (a) Propogation of acute aortic dissection is dependent on arterial BP and shear stress (force of left ventricular contraction as a function of time).
         (b) HR and contractility control can minimize shear stress and, together with BP, become a target of management.
         (c) Goal HR less than 60 beats/minute and SBP less than 100 mm Hg as soon as possible (within 5–10 minutes)
      ii. Acute ischemic stroke
         (a) Hypertension with ischemic stroke is an adaptive response to maintain cerebral perfusion pressure to the brain.
         (b) Cerebral perfusion pressure equals mean arterial pressure minus intracraial pressure: CPP = MAP – ICP.

(c) Treatment should occur only if thrombolytic therapy is required (goal SBP less than 185 mm Hg and DBP less than 100 mm Hg to decrease risk of bleeding), other target organ damage occurs, or SBP is greater than 220 mm Hg and/or DBP is greater than 120 mm Hg.

(d) Goal 15%–20% MAP reduction over 24 hours (Cardiol Clin 2012;30:533-43)

iii. Intracranial hemorrhage

(a) BP reduction goals will be based on individual factors, including medical history; ICP, if known; demographics such as age; presumed cause of hemorrhage (e.g., arteriovenous malformation); and interval since onset.

(b) Theoretical risk of worsening bleeding with uncontrolled BP must be balanced with risk of decreased cerebral perfusion pressure with overly aggressive treatment.

(c) Patients can tolerate a BP reduction in SBP of 180 mm Hg or less and/or a MAP less than 130 mm Hg over 24 hours (Crit Care Med 2006;34:1975-80).

(d) Retrospective data showed an increased rate of death with a more rapid BP reduction in the acute hospital setting (Crit Care Med 1999;27:480-5).

3. Agents for BP management of hypertensive emergency

a. The drug of choice for hypertensive emergency is intravenous nitroprusside.

i. Intravenous nitroprusside works rapidly and is safe in the presence of renal and/or hepatic impairment for short-term use (24 hours or less).

ii. Continuous BP monitoring (e.g., arterial line) is recommended with use because rapid changes can occur.

iii. Nitroprusside can increase ICP and may result in coronary steal; caution or avoidance should be considered in patients with elevated ICP and acute mycocardial ischemia/infarction.

b. Table 8 summarizes available agents, dosing, onset, duration, and hemodynamic considerations. Table 9 summarizes possible indications and special considerations.

Table 8. Medications Used in Hypertensive Emergencies

Medication	Usual Dosing Range	Onset	Duration	Preload	Afterload	Cardiac Output
Nitroprusside	IV 0.25–10 mcg/kg/min Titrate by 0.1–0.2 mcg/kg/min q5 min	Seconds	1–2 min	↓	↓↓	↑
Hydralazine	IV bolus: 10–20 mg IM: 10–40 mg q30 min prn	IV: 10 min IM: 20 min	IV: 1–4 hr IM: 2–6 hr	↔	↓	↑
Nicardipine	IV 5–15 mg/hr Titrate by 2.5 mg/hr q5–10 min	5–10 min	2–6 hr	↔	↓	↑
Clevidipine	IV 1–6 mg/hr Titrate by 1–2 mg/hr q90s. Max 32 mg/hr	1–4 min	5–15 min	↔	↓	↑
Nitroglycerin	IV 5–200 mcg/min Titrate by 5–25 mcg/min q5–10 min	2–5 min	5–10 min	↓↓	↓↔	↔↑

Table 8. Medications Used in Hypertensive Emergencies *(continued)*

Medication	Usual Dosing Range	Onset	Duration	Preload	Afterload	Cardiac Output
Esmolol	IV 25–300 mcg/kg/min (bolus of 0.5 mg/kg, not often required given short onset) Titrate by 25 mcg/kg/min q3–5 min	1–2 min	10–20 min	↔	↔	↓
Metoprolol	IV bolus: 5–15 mg q5–15 min prn	5–20 min	2–6 hr	↔	↔	↓
Labetolol	IV bolus: 20 mg, may repeat escalating doses of 20–80 mg q5–10 min prn IV 1–2 mg/min Titrate by 1–2 mg/min q2 hr given longer half-life	2–5 min, peak 5–15 min	2–6 hr	↔	↓	↓
Enalaprilat	IV bolus: 1.25 mg q6 hr Titrate no more than q12–24 hr; max dose 5 mg q6 hr	15–30 min	12–24 hr	↓	↓	↑
Phentolamine	IV bolus: 1–5 mg prn; max 15 mg	Seconds	15 min	↔	↓	↑
Fenoldopam	IV 0.03–1.6 mcg/kg/min Titrate by 0.05–1 mcg/kg/min q15 min	10–15 min	10–15 min	↔ ↓	↓	↑

IM = intramuscular; IV = intravenous.

Table 9. Indications and Special Considerations for Medications Used for Hypertensive Emergencies

Medication	Indication	Special Consideration
Nitroprusside	Most indications (excluding conditions with ICP elevation and coronary infarction/ischemia caused by coronary steal)	• Liver failure – cyanide accumulation • Renal failure – thiocyanate accumulation • Can draw serum cyanide and thiocynate concentrations to monitor • Toxicity associated with prolonged infusions (> 72 hr) or high doses (> 3 mcg/kg/min) • May result in coronary steal • Increases ICP
Hydralazine	Pregnancy	• Can result in prolonged hypotension (less predictable dose response) • Risk of reflex tachycardia • Headaches, lupus-like syndrome (with long-term use)
Nicardipine	Acute ischemic or hemorrhagic stroke	• Risk of reflex tachycardia • Infusion can lead to large fluid volumes administered

Table 9. Indications and Special Considerations for Medications Used for Hypertensive Emergencies *(continued)*

Medication	Indication	Special Consideration
Clevidipine	Acute ischemic or hemorrhagic stroke	• Formulated in oil-in-water formulation providing 2 kcal/mL of lipid calories • Caution for patients allergic to soy or eggs
Nitroglycerin	Coronary ishemia/ infarction Acute left ventricular failure Pulmonary edema	• Tachyphylaxis occurs rapidly, requiring dose titrations • Adverse effects: Flushing, headache, erythema; often dose-limiting adverse effects • Veno > arterial vasodilator
Esmolol	Aortic dissection Coronary ischemia/ infarction	• Contraindicated in acute decompensated heart failure • Should be used in conjunction with an arterial vasodilator for BP management in aortic dissection (initiate esmolol first because of the delayed onset relative to vasodilators such as nitroprusside) • Metabolism is organ-independent (hydrolyzed by esterases in blood) • Useful in tachyarrhythmias
Metoprolol	Aortic dissection Coronary ischemia/ infarction	• Contraindicated in acute decompensated heart failure • Should be used in conjunction with an arterial vasolidator for BP management in aortic dissection (initiate metoprolol first because of the delayed onset relative to vasodilators such as nitroprusside) • Useful in tachyarrhythmias
Labetalol	Acute ishemic or hemorrhagic stroke Aortic dissection Coronary ischemia/ infarction Pregnancy	• May be used as monotherapy in acute aortic dissection • Contraindicated in acute decompensated heart failure • Prolonged hypotension may be experienced with over-treatment; dose cautiously
Enalaprilat	Acute left ventricular failure	• Contraindicated in pregnancy • Caution in dose adjustments given prolonged duration of action
Phentolamine	Catecholamine excess (e.g., pheochromocytoma)	• Use in cathecholamine-induced hypertensive emergency
Fenoldopam	Most indications	• Risk of reflex tachycardia • Caution with glaucoma • Can cause hypokalemia, flushing • May increase ICP

ICH = intracranial hemorrhage; ICP = intracranial pressure.

c. Certain populations require specific medication therapy approaches:
   i. Pregnancy
      (a) Severe preeclampsia can only be managed by delivery of the baby.
      (b) Magnesium can be considered as an adjunctive therapy to decrease seizure risk or if seizures develop.
      (c) Intravenous medications should only be considered for persistently elevated BPs (SBP greater than 160 mm Hg and/or DBP greater than 110 mm Hg).

(d) Hydralazine and labetalol are feasible first-line options, and labetalol may have fewer adverse effects (Am J Health Syst Pharm 2009;66:337-44).

ii. Catecholamine-induced hypertensive emergency

(a) Phentolamine is the drug of choice because it competively inhibits α-adrenergic receptors.

(b) β-Antagonists are contraindicated unless the patient is fully α-blocked.

(c) Cocaine-induced hypertensive emergency (Ann Emerg Med 2008;52:S18-20; Chest 2007;131:1949-62)

(1) Benzodiazepines are used to target the central effects of cocaine as first-line therapy and often will result in control of tachycardia and hypertension. Diazepam 5–10 mg intravenously or lorazepam 2–4 mg intravenously titrated to effect

(2) If central control of cocaine-induced hypertension fails, consider direct α-antagonism with phentolamine. Phentolamine 1 mg intravenously; repeat every 5 minutes as needed

(3) If direct α-antagonism does not gain control, consider additional antihypertensives:

(A) Nitroglycerin, nicardipine, nitroprusside, or fenoldopam titrated to effect are viable options (see Table 7 for dosing and consideration).

(B) Verapamil and diltiazem decrease coronary vasospasm associated with acute cocaine intoxiciation (Am J Cardiol 1994;73:510-3).

(C) Controvery exists regarding the use of β-blockers.

- Labetaolol has shown conflicting results regarding ability to control MAP but not alleviate cocaine-induced coronary vasoconstriction.
- Consensus opinion recommends β-blockers only if full α-antagonism is employed first.

d. All intravenous medications should be transitioned to oral medications as soon as possible.

i. Oral antihypertensives should be initiated within 24 hours.

ii. Medication history and reconciliation can assist in resuming home regimens.

iii. Additional or new agents should be selected according to disease-specific indications.

Patient Case

8. B.B. is a 44-year-man with no medical history who presents to the ED with a ripping sensation in his chest. His social history includes cigarette smoking, 1.5 packs/day for the past 20 years. Chest radiography in the ED reveals mediastinal widening. Cardiac enzymes are within normal limits. Laboratory values include sodium (Na^+) 135 mEq/L, potassium (K+) 4.3 mEq/L, bicarbonate (HCO3-) 24 mEq/L, SCr 0.55 mg/dL, glucose 110 mg/dL, DBil 0.2 mg/dL, and AST 39 U/L. B.B. is rushed for a chest CT and angiography, which reveal an acute type A and B aortic dissection. His vital signs include BP 208/140 mm Hg and HR 120 beats/minute. Which is most appropriate regarding B.B.'s BP management?

A. B.B.'s BP reduction goal is a 25% reduction in MAP over the first 60 minutes, which can be accomplished with esmolol as first line.

B. B.B.'s BP reduction goal is a reduction to 160/100 mm Hg over the first 24 hours, which can be accomplished with initation of hydrochlorothiazide and lisinopril.

C. B.B.'s goals include BP and HR, which would be a 25% reduction in MAP and HR less than 60 beats/minute in the first 60 minutes, and can be accomplished with labetalol as first line.

D. B.B.'s goals include BP and HR, which would be an SBP less than 100 mm Hg and an HR less than 60 beats/minute as soon as possible with esmolol with or without nitroprusside as first line.

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ANSWERS AND EXPLANATIONS TO PATIENT CASES

1. Answer: B

Because rescuer fatigue is common and may lead to inadequate compression quality, it is recommended to change rescuers every 2 minutes, with no more than 5 seconds between changes. Compressions are vital because they increase intrathoracic pressure and directly compress the heart, leading to oxygen delivery to the vital organs. Specific aspects of chest compression quality are necessary. These include a rate of at least 100 compressions/minute at a depth of 2 inches in adults, allowing for recoil after each compression; placement of the patient on a hard surface (e.g., backboard); and minimization of interruptions. Outcomes, including neurologically intact survival, ROSC, and possibly overall survival, are linked to minimizing interruptions in chest compressions. Because of this, it is recommended that interruptions (e.g., pulse checks and intubation) be less than 10 seconds and that chest compressions be resumed immediately.

2. Answer: C

Cardiac arrest patients have minimal blood flow, and oxygenation/ventilation requirements are lower; the current compression/ventilation ratio recommended is 30:2. Although the optimal ratio is unclear and chest compressions appear to be more vital to resuscitation, other ratios cannot currently be recommended. It is clear, however, that excessive ventilation can lead to decreased venous return and gastric inflation, which can lead to aspiration, regurgitation, and impacts on outcomes. In this case, a bag-mask ventilator is available, and multiple rescuers are involved, so the bag-mask ventilator should be used. In single-rescuer situations, the bag-mask ventilator should never be used, and mouth-to-mouth or mouth-to-barrier resuscitation is recommended. Advanced airways can be considered but should be placed only by experienced and trained personnel. Bag-mask ventilation can provide adequate oxygenation/ventilation until an airway can be secured.

3. Answer: A

Three vital actions with VF aid in survival: call emergency response team (already accomplished in case), begin CPR (needs to be initiated in case), and deliver shock (needs to occur in case). Pacing can be effective in overriding stable VT but should not be used in the cardiac arrest or hemodynamically unstable patient. It is currently unclear whether postponing defibrillation for the provision of chest compressions first is of benefit, but it is clear that chest compressions should be initiated until the defibrillator is ready, charged, and set to deliver the shock because this increases the likelihood of success with defibrillation. Because time in VF predicts survival and the longer patients are in VF, the more difficult it is to terminate the arrhythmia, alternative treatments such as medications should not impede the provision of defibrillation.

4. Answer: D

After the advanced airway is in place, it is crucial to confirm placement in order to provide the intended oxygenation/ventilation. The confirmation should occur with both clinical and objective measurements. These include a physical assessment of the chest and epigastrium, end-tidal CO_2 monitoring, and/or continuous waveform capnography. In most cardiac arrests (particularly in this patient's pulseless VT), airway management should not impede the provision of CPR and/or defibrillation (when defibrillation is indicated). After the advanced airway is in place, 100% oxygen should be delivered to optimize the arterial oxygen saturation. In the cardiac arrest population, this has not been shown to carry the same toxicity as in other populations. Furthermore, after advanced airway is placed, compressions should be administered at a rate of at least 100 compressions/minute continuously, with breaths given 6–8 times per minute.

5. Answer: B

In all cardiac arrests, the treatable causes (i.e., H's and T's) should be reviewed and addressed, if possible. In patients for whom the laboratory and diagnostic data are known, the information should be reviewed while CPR is being provided. In patients for whom the information is unknown, clinical evaluation and attainment of information should occur, when possible. This retrieval of information, together with the administration of medications and advanced airway placement, should never impede on the provision of CPR or defibrillation, if indicated, because defibrillation (for VF and pulseless VT) and CPR are the only strategies that have been shown to affect survival from cardiac arrest. Pulseless electrical

activity and asystole are not wide complex rhythms, and defibrillation would not be indicated if either were detected. Post–cardiac arrest care is crucial in the prevention of re-arrest and, in therapeutic hypothermia, can significantly affect neurologic outcomes.

6. Answer: D

In general, it is important to remember that medication administration benefits only myocardial blood flow and ROSC in cardiac arrest. Medication administration should never impede the provision of CPR and/or defibrillation. Central administration is preferred for several reasons. These include higher peak concentrations, shorter circulation time, more standard dosing, and the lack of additional administration techniques needed. Endotracheal administration is an option, but only NAVEL (naloxone, atropine, vasopressin, epinephrine, and lidocaine) medications can be administered, the optimal doses are unknown, and medications must be diluted before administered. Given that this patient is in VF arrest, amiodarone, for example, could not be administered by endotracheal administration if it were indicated. Peripheral administration can be used, but it requires an additional bolus of fluid afterward and has a longer circulating time than does central administration. Intraosseous can also be used, with the caveat that intraosseous administration is similar to peripheral administration.

7. Answer: B

Targeted temperature management (therapeutic hypothermia) improves neurologic recovery when initiated, optimally within 2 hours but in up to 6–8 hours for VF cardiac arrest (application to all forms), and employed for 12–24 hours. The goal temperature is 32°C–34°C. Newer data suggest there is no benefit of 33°C versus 36°C in improvement of survival or neurologic outcomes. If targeted temperature management will be used, close monitoring of complications should occur. These complications include hyperglycemia caused by decreased insulin production and peripheral activity, bradycardias, enzymatic slowing (including cytochrome P450 system), increased incidence of sepsis and infections, coagulopathies, decreased glomerular filtration, and shivering.

8. Answer: D

This patient is experiencing a hypertensive emergency with his target organ damage being an acute aortic dissection. Aortic dissection is one of the unique hypertensive emergencies that has a unique mechanism of worsening (propogation) from BP and shear stress, which require both rapid BP and HR control. Given the gravity of propogation, goals for aortic dissection are HR less than 60 beats/minute and SBP less than 100 mm Hg within minutes, if possible. This can be accomplished with either a single agent like labetalol, which will control HR with its β-antagonist properties and decrease BP (afterload) with its α-antagonist properties. Esmolol can also be used as first line but will likely require an additional afterload-reducing agent such as nitroprusside.

ANSWERS AND EXPLANATIONS TO SELF-ASSESSMENT QUESTIONS

1. Answer: C

The largest portion of adult cardiac arrests are caused by cardiovascular, not respiratory, events. In addition, this patient was on room air and nasal cannula immediately before the event, which could suggest his respiratory status was stable and unlikely to lead to cardiac arrest. Advanced airways and medications have only been shown to facilitate ROSC in cardiac arrest in contrast to chest compressions and defibrillation (if indicated), which can improve survival. Because of this, CPR should begin immediately for this patient, starting with chest compressions in accordance with the BLS guidelines with pads placed simultaneously to facilitate rapid defibrillation if the patient's rhythm reveals a shockable rhythm.

2. Answer: A

The cornerstone of therapy for VF cardiac arrest is rapid defibrillation. The recommended dosage of voltage for biphasic defibrillators is 200 J or the manufacturer's recommendation (often the same dosage). Although amiodarone is in the treatment algorithm for VF cardiac arrest, it is reserved and recommended for refractory VF cardiac arrest, which is defined as defibrillation refractory. Therefore, defibrillation should occur first. Atropine has been removed from the cardiac arrest algorithms for PEA and asystole because of a lack of benefit on outcomes and should be not be considered for VF cardiac arrest. Pacing has not shown benefit in the cardiac arrest situation and should not be used.

3. Answer: B

Because the rhythm detected is PEA and no longer VF, the cornerstone of therapy changes from giving defibrillation to giving high-quality chest compressions and addressing the treatable causes of cardiac arrest (H's and T's). Lidocaine is reserved for refractory VF/pulseless VT (defined as defibrillator refractory) when amiodarone is unavailable. Atropine was previously recommended for PEA/asystole, but in the 2010 ACLS guidelines, it was removed because of a lack of data supporting any beneficial outcomes. Therefore, the correct answer for this patient would be targeting high-quality chest compressions and reversing any treatable causes.

4. Answer: C

Targeted temperature management is a consideration according to the international guidelines for all patients with ROSC who remain comatose after a cardiac arrest. Although most well-designed and executed studies primary enrolled patients with VF cardiac arrest, application is recommended for all patients with a cardiac arrest independent of rhythm. Although worsening trasaminitis and hepatic enzymatic function slowing is likely to occur during hypothermia, neither of these principles would be considered a contraindication for hypothermia. Furthermore, renal function in terms of glomerular filtration worsens which requires viginlant monitoring of renal function and close attention paid to renal dose modifications and serum concentration monitoring of medications when applicable. An additional complication of therapeutic hypothermia is an induced coagulopathy which leads patients to be at risk of bleeding. Thrombolytics may carry specific indications for cardiac arrest (e.g., pulmonary embolism or acute coronary syndromes), but they would not be recommended empirically.

5. Answer: B

Therapeutic hypothermia improves neurologic recovery in patients after a cardiac arrest. Most patients included in randomized clinical trials are patients who have VF as their causative rhythm. Because of its impact on neurologic recovery, guideline recommendations have applied this literature to cardiac arrests of all rhythms and many instutitions have adopted this same recommendation. Recent studies targeting mild hypothermia (36°C vs. 33°C) have shown no difference regarding outcomes between the two modalities, and because of this, some question of the utility of hyptohermia at all in an era of potentially more advanced cardiac arrest care.

6. Answer: D

By definition, this patient is having a hypertensive emergency because she has an abrupt, severe increase in BP with target organ damage—in this case, potentially shock liver and vision changes. Hypertensive urgency would be defined by a systolic blood pressure (SBP) greater than 180 mm Hg and/or a diastolic blood pressure (DBP) greater than 110 mm Hg without evidence of target organ damage. But given the patient's presentation, she would be classified as having a hypertensive emergency.

7. Answer: C

The patient should be initiated on nitroprusside for BP management. Although she has transaminitis, nitroprusside can be used safely in the first 24 hours in these patients. Phentolamine would be reserved for hypertenisve crisis that presents from a catecholamine crisis. Oral metoprolol might be an appropriate option to transition to after the emergency is resolved, but because of the target organ damage, more rapid reduction is needed using an intravenous agent such as nitroprusside. Enalaprilat is an option, but 10 mg every 6 hours would not be an appropriate starting dose because it would put the patient at risk of overshooting and, given the long duration of activity, could lead to unwanted consequences.

8. Answer: A

The initial goal reduction for J.H.'s BP, given that he is experiencing a hypertensive emergency, is a 25% reduction in MAP within the first 60 minutes. More rapid BP reductions may result in a lack of cerebral perfusion; therefore, they are not recommended. J.H. is not experiencing any of the unique hypertensive emergencies (e.g., aortic dissection) that would call for a more rapid BP reduction. In addition, J.H. is not experiencing a hypertensive emergency that would require a slower BP reduction (e.g., stroke).